THE GEOLOGY OF
Winnipesaukee Quadrangle
NEW HAMPSHIRE

By

ALONZO QUINN

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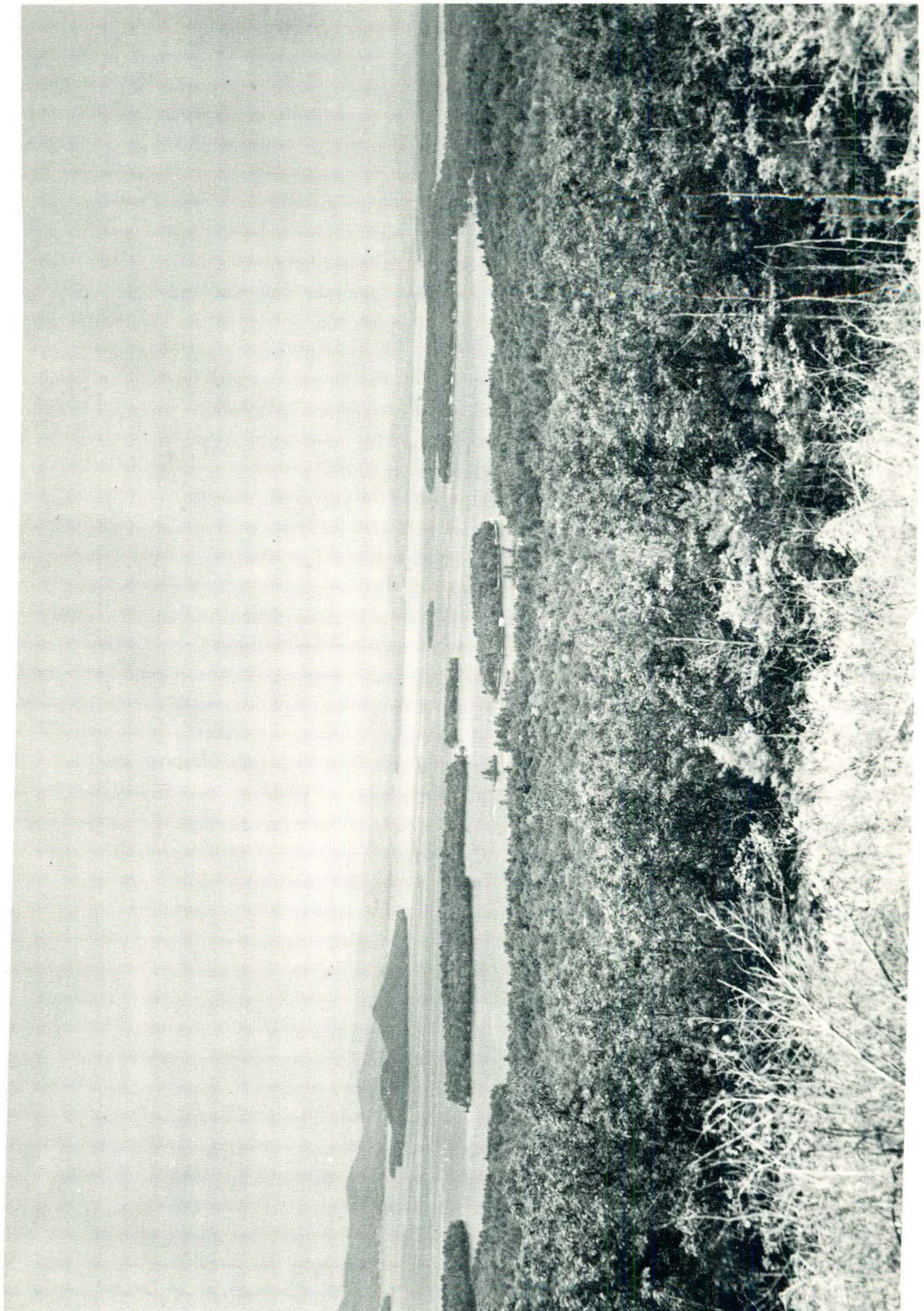

Geology

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Winnipesaukee Quadrangle

New Hampshire

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Foreword

This pamphlet is not intended to be an elaborate scientific report for the professional geologist, but is written for the layman, in simple language with few scientific names. The map accompanying the pamphlet shows the details of the geology of the region, and has a legend for reading it. All that need concern the layman are the formation names and it is not essential for him to read or understand the detailed mineral and rock descriptions in the legend. The story of the rocks can be understood without these details.

The field work was carried on under the auspices of the Department of Geology of Brown University, the Division of Geological Sciences of Harvard University, and the Department of Geology of Bryn Mawr College. Mr. R. N. Palmer furnished transportation by boat to a number of islands in Lake Winnipesaukee. The geological map was contributed by the New Hampshire Highway Department, and the publication of this pamphlet was financed by a special revolving fund set aside in 1934 from the State Highway Fund for that purpose.

Geology of the Winnipesaukee Quadrangle New Hampshire

By Alonzo Quinn

INTRODUCTION

THE Winnipesaukee quadrangle, in the east-central part of New Hampshire, is widely known for its summer resorts, camps, and other vacation places. Several hundreds of summer cottages are located here, on Lake Winnipesaukee and other lakes, and many of the farms away from the lakes have been made over into summer homes. Resorts for winter sports have also been developed during the last few years, especially in the Belknap Mountains. For these reasons the area is known to a host of people and it is hoped that this pamphlet and the geological map will add to their understanding and enjoyment of the scenery.

Ever-inquisitive geologists have learned through patient study that this beautiful area has gone through a long and complicated history. Ancient seas lay here for millions of years. The rocks were once mashed and squeezed by earth-forces beyond our comprehension. This has not always been a quiet and peaceful place, for volcanoes once thundered with violent explosions. Even the ice had its turn at fashioning this land, and was here only yesterday, geologically speaking.

THE LANDSCAPE

The dominant scenic feature of the area is Lake Winnipesaukee, and the lowland in which it lies is one of the largest topographic units in the entire state. This lowland was formed by the erosion of a great area of weak rocks by streams and by glacial ice into low hills and gentle valleys; later sand, clay, and other loose materials were deposited irregularly by the melting ice. Melt-water from the ice first filled the depressions caused by these irregular deposits and made lakes; rain has since kept them filled. The ridges and hills that were too high to be submerged are the present peninsulas and islands.

Rising above the Winnipesaukee lowland are three areas of considerably higher land, the Belknap Mountains, the Ossipee Mountains, and Red Hill. The geological map and later parts of this pamphlet will show that the lowland and lake are underlaid mainly by one type of rock and that the three higher areas are underlaid by other types of rock. The rock of the lowland is weak and the lowland is due to its more rapid erosion. The higher areas are made of more resistant rocks. Erosion attacks them all, but some succumb more readily than others. This principle of differential erosion can be applied in this region only in a general way and it cannot be said that each hill is underlaid by resistant rock or that each valley was eroded in weak rock. See figure 1.

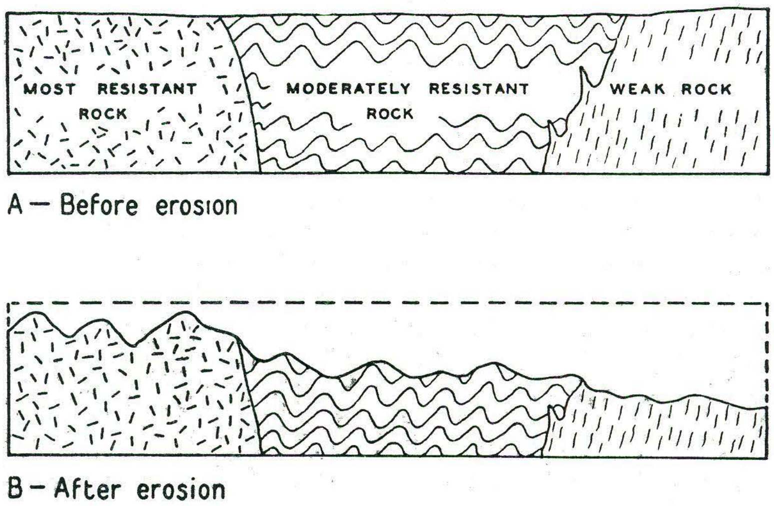

Figure 1.

Diagrammatic cross-section representing the differential erosion of three groups of rocks of different resistance. In A a flat plain once near sea level has been uplifted several thousand feet so that erosion attacks it vigorously. B represents the same region after prolonged erosion. The whole area has been cut down, but by unequal amounts depending on varying resistance of the rocks. The major differences of elevation are due, therefore, to the character of the rock, but it should be noticed that within each type of rock there are hills and valleys, due to other factors. In the Winnipesaukee quadrangle the rocks of the White Mountain magma series are the most resistant, the schists of the Littleton formation and the Meredith porphyritic granite are moderately resistant, and the Winnipesaukee quartz diorite is weak.

THE ROCKS AND THEIR STORY

Major Units

The rocks of this quadrangle may be divided into three main groups on the basis of origin and age. The oldest is a group of schists belonging to the Littleton formation and found mainly in the southwestern part of the area. The second group of rocks has two members which underlie almost the whole of the lowland. Both are igneous in origin (*i. e.,* they were once molten) and belong to what has been called the New Hampshire magma series. The third group includes a great variety of igneous rocks, which are found in the three higher areas, the Belknap Mountains, the Ossipee Mountains, and Red Hill. These rocks are related to each other in age and origin and are members of the White Mountain magma series.

Littleton Formation

The Littleton formation consists of schists which generally have a brown rusty appearance because of the iron oxides which stain them. The chief minerals are quartz, black mica, white mica, and garnet. The abundant mica flakes are usually parallel to one another; this gives the rock a banded appearance. This banding is known as schistosity or foliation. A striking phenomenon at many outcrops is the extreme twisting or folding of the foliation. This is plainly due to the intense squeezing which once affected this part of the crust of the earth.

These schists have gone through such a complicated history that their origin is not apparent, but geologists have learned that they were originally layers of sand and mud deposited in water. From the relations to other rocks in various parts of this region it is believed that the body of water in which these layers were deposited was probably a shallow sea of early Devonian time (about 350 million years ago).

After these muds and sands had accumulated on the sea floor for perhaps a million years and were a thousand feet or more thick, the sea withdrew and the whole region was caught by tremendous horizontal pressure and squeezed into sharp folds. This great pressure and the accompanying heat caused the chemical elements of the mud and sand to rearrange themselves into white mica, black mica, quartz, and garnet. As a result of the squeezing, the mica flakes lie parallel to each other, and long-continued folding caused the contortion that can be seen in many outcrops of the schist. This is the process known as metamorphism and these schists are metamorphic rocks. The whole process took place when the present surface rocks were deeply buried in the earth, perhaps a mile or more. Their presence at the surface now is due to prolonged erosion which stripped off the overlying rocks.

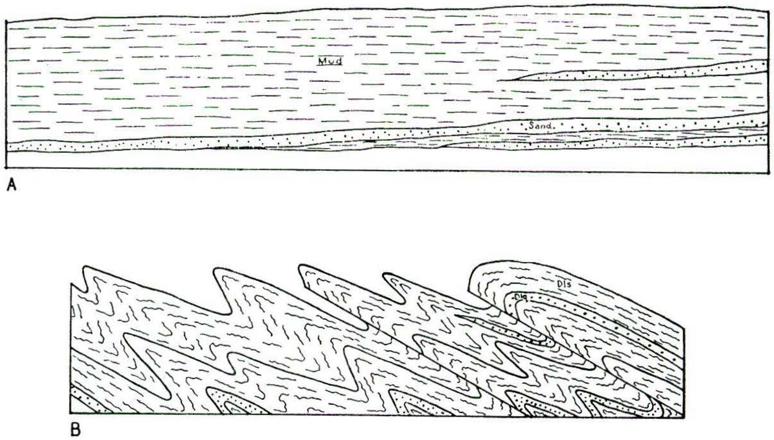

Figure 2

A. A thousand feet or more of mud and sand were deposited in an early Devonian sea. (The floor on which these sediments were deposited is not exposed in the Winnipesaukee area.)

B. The whole region was caught by tremendous horizontal pressure and squeezed into sharp folds. Locally blocks of rock slid past each other along fractures known as faults. The layers of mud and sand were recrystallized by the pressure and heat into schists. Effects of contemporaneous erosion omitted. D1s = schist, derived from mud. D1q = quartzite, derived from sand.

New Hampshire Magma Series

Both of the members of this series are granite in popular terminology, but one is called quartz diorite on the basis of microscopic examination. Similar as they are in composition, their appearance is rather different.

These rocks of the New Hampshire magma series were formed from molten material within the earth. Liquid magma in great quantities began working its way up from within the earth where the temperatures are very high. As the liquid moved upward it came into contact with cooler rocks and finally lost so much heat that it solidified before reaching the surface of the earth. The solidification took place slowly at a depth of a mile or so, and later erosion has exposed the rocks to view. It is apparent that these granites are younger than the schists, because they cut across the

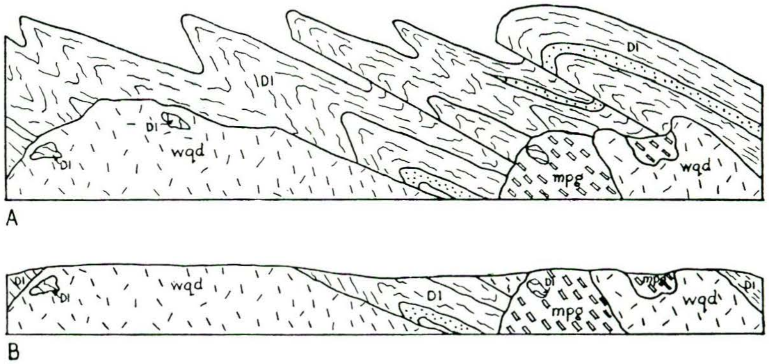

Figure 3

A. Liquid Meredith porphyritic granite (mpg) and Winnipesaukee quartz diorite (wqd) worked their way up into the Littleton schist (D1) and solidified there at considerable depth.

B. Erosion through millions of years removed much of the Littleton schist (D1) from this area and exposed the Meredith porphyritic granite (mpg) and Winnipesaukee quartz diorite (wqd).

schists and because fragments and slivers of the schists are enclosed by the granites. These relationships may be seen at several places in Meredith, for example, in the vicinity of Little Pond, Millstone Hill and the small hills north of it, and at Pinnacle Hill.

It is believed that the two granites came in at about the same time, probably late Devonian (300,000,000 years ago), but that the Meredith porphyritic granite is the older of the two. This age relationship of the Meredith porphyritic granite and the Winnipesaukee quartz diorite is shown by outcrops near the southeast corner of the map, on the upper slopes of Cedar Mountain, where many blocks of the Meredith porphyritic granite are included in the Winnipesaukee quartz diorite. The geologist's interpretation is that solid pieces of the Meredith porphyritic granite were once floating in the still liquid Winnipesaukee quartz diorite. (See figure 4).

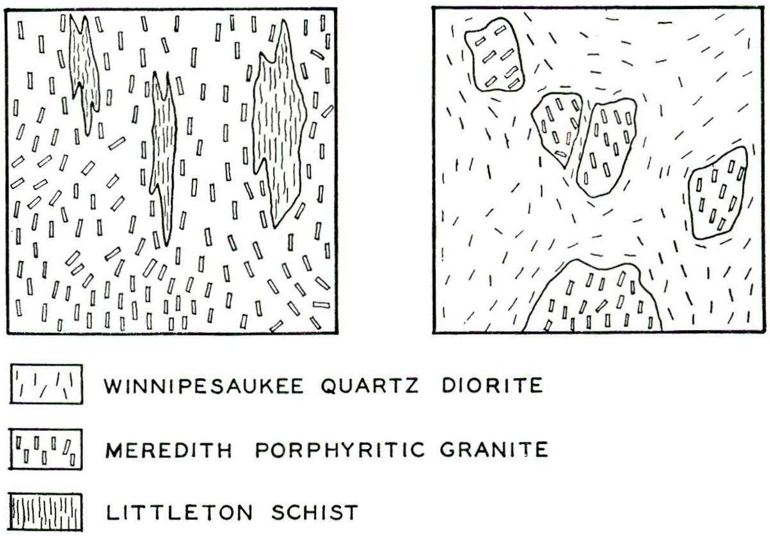

Figure 4

Diagrams showing some of the evidence used by geologists to tell which rocks are older and which are younger (these relationships do not tell the ages in years). They may be considered as either cross-sections or as maps.

A. The schist is older, because (a) it has extreme foliation which shows that it was squeezed; the Meredith porphyritic granite does not have foliation and was not squeezed; we conclude that the granite did not exist when the shearing occurred; (b) the angular shape of the schist blocks shows it was solid while the still liquid granite engulfed it. The schist blocks, or inclusions, may be a few feet or a quarter of a mile across.

B. Inclusions of Meredith porphyritic granite (older) in Winnipesaukee quartz diorite (younger), Cedar Mountain. The fact that the angular blocks of Meredith porphyritic granite are entirely surrounded by the Winnipesaukee quartz diorite shows that the Meredith porphyritic granite was solidified first and is older. The inclusions are a few feet across.

The Meredith porphyritic granite has a very striking appearance because of the oblong crystals of white feldspar, two inches or more in length. Most of these big feldspar crystals show reflection of light from only half the crystal in one position and from the other half in another position. The mineralogist recognizes this as an indication that the crystal is a "Carlsbad twin." The other main minerals of this rock are quartz and black mica. Small garnets are common, and here and there one sees tiny white fibers of sillimanite. An excellent place to see this rock is the Meredith trap quarry, at Dudley Leavitt's, between Center Harbor and Meredith. The granite is there cut across by a large, irregular, almost flat-lying dike of trap rock which is quarried for road metal. Incidentally, the way this black trap dike cuts through the granite shows that the granite was there first and that the molten trap was forced up into a fracture in the granite. The granite is also well exposed on the tops of several of the higher hills, such as Sunset Hill, Gilman Hill, and Pinnacle Hill. At Pinnacle Hill there are several long slivers of schist enclosed by the granite. In addition, there are on this hill excellent examples of glacial scratches on the schist. These scratches show not only that the glacier once rode over this hill, but they also show by their direction that the ice was moving southeastward.

The Winnipesaukee quartz diorite is common gray granite without the unusually large feldspar crystals of the Meredith porphyritic granite. It is composed of feldspar, quartz, and black mica. In many places it is foliated, or banded, but at others it is quite massive. It commonly has streaks of very coarse granite (pegmatite) and very fine granite (aplite) cutting through it. The Winnipesaukee quartz diorite is the weak rock which has been eroded to form the great lowland of the lake country in central New Hampshire.

On Mark Island and in places on Bear Island the Winnipesaukee quartz diorite has black hornblende in addition to other minerals.

The coarse pegmatite is commonly composed of feldspar, quartz, and micas only, but on Long Island and on Mark Island one finds also, though rarely, green beryl and black glossy tourmaline.

A long period of erosion intervened before the next group of rocks, the White Mountain magma series, was formed.

White Mountain Magma Series

In the White Mountain district of New Hampshire and vicinity there is an important group of igneous rocks which have mineral compositions, structural characteristics, and age relationships that set them apart from the other rocks. They are known as the White Mountain magma series and appear in the Winnipesaukee quadrangle at the Belknap Mountains, the Ossipee Mountains, and Red Hill. These are the rocks that tell us there were once great volcanic eruptions here. The areas shown by the map to be underlaid by Moat volcanics are composed of lava and exploded material from volcanoes. There are also rocks in this group which were formed by the solidifying of magma below the surface. Erosion has left only remnants of the volcanic rocks which were formed at the surface and has exposed those that cooled beneath the surface. They now appear grouped together in great variety in relatively small areas. Generally they are in small oval areas or in curved narrow bands, which may loop around and may even form large circular areas, as the Ossipee Mountains.

Accompanying the larger bodies of igneous rocks are hundreds of dikes of many types. They generally appear as black bands cutting across the enclosing rock. They were formed when molten magma filled fractures in the older rock and solidified there. These dikes are to be seen at many places throughout the area, on hill tops, in road cuts, along the shore, and elsewhere. Black dikes are more common in this area but there are also light colored dikes. Fine-grained black rock in a dike is known as trap or trap-rock.

Some of the unusual characteristics of the White Mountain magma series are best understood by examination of particular areas.

In the *Belknap Mountains* there is a large and spectacular variety of rocks, as in the other areas of the White Mountain magma series. A rock of very unusual appearance is the breccia of diorite in Conway granite. First, a great area of dark diorite was formed. Then it was broken into millions of pieces and cut through by pink Conway granite. This breccia is exposed very well at the ski jump and along the chair tramway near Poorfarm Brook. The angular patchwork of dark diorite and pink granite is rather striking. Another unusual rock may be seen on the hill (Rowes Hill), just northwest of the ski jump. It is part of the filling of the throat of an old volcano and is composed of fragments of several types of rock which were shattered by the explosions and which fell back into the vent. It has long since become solidified into a hard rock. Along Poorfarm Brook where the road from the ski jump joins the main road is a good exposure of a peculiar dark dike with many inclusions of light syenite. It was formed as the dark magma filled in between the fragments of a shattered zone in the syenite. Nearby is a "rottenstone" quarry, where the syenite has been deeply weathered, so that what was once firm rock now crumbles in one's hands.

Spectacular exposures of the contact of the Albany quartz syenite and the Meredith porphyritic granite may be seen on the top of Mt. Major and the hill one and a third miles east of Round Pond. Excellent exposures may be seen on Piper Mountain, Belknap Mountain, and Gunstock Mountain. In fact, the upper slopes of all the higher hills in the Belknaps have unusually good exposures.

The Belknap Mountains area shows superb examples of a peculiar type of geological structure known as a "ring-dike." Only part of the Belknap Mountains lies in the Winnipesaukee quadrangle; the rest is in the adjacent Gilmanton, Alton, and Wolfeboro quadrangles. Figure 5, in which the geology has been simplified by grouping under one symbol rocks that are closely related in age and composition, has been prepared to show the whole area.

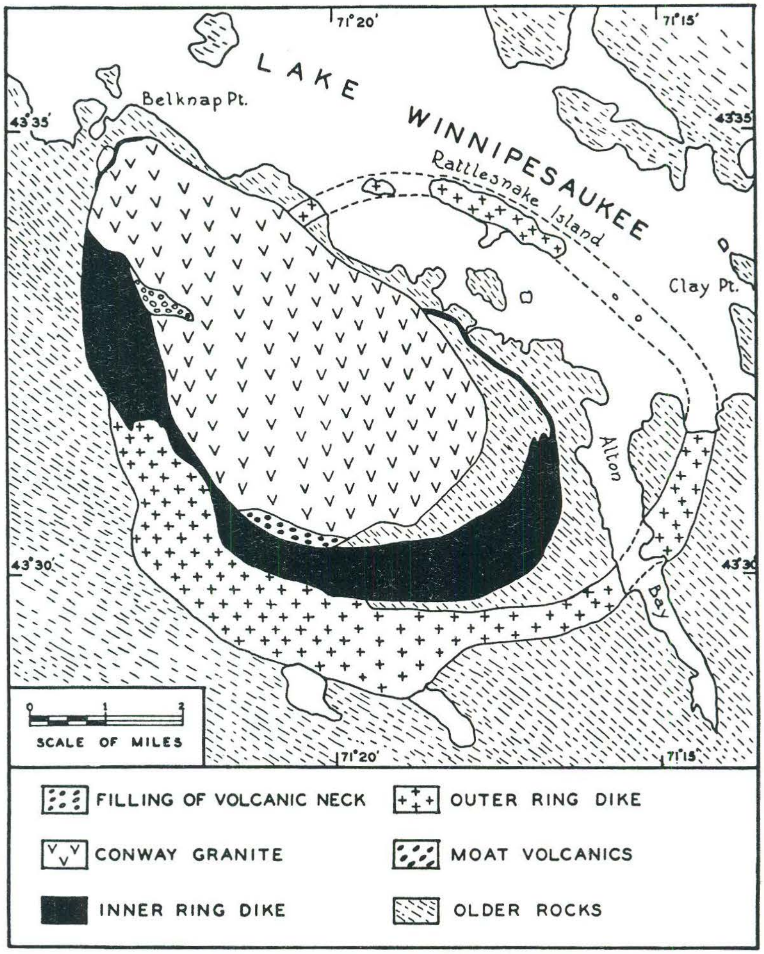

Figure 5

Simplified geological map of the Belknap Mountains and vicinity.

Figure 6 portrays the history of the Belknap Mountains, somewhat simplified also. First (Figure 6A) a great thickness of volcanic rocks was poured out and blown out over the surface until probably much of the quadrangle was covered. They are called the Moat volcanics, from Moat Mountain near Conway, where the true nature of these rocks was first recognized (Figure 6B).

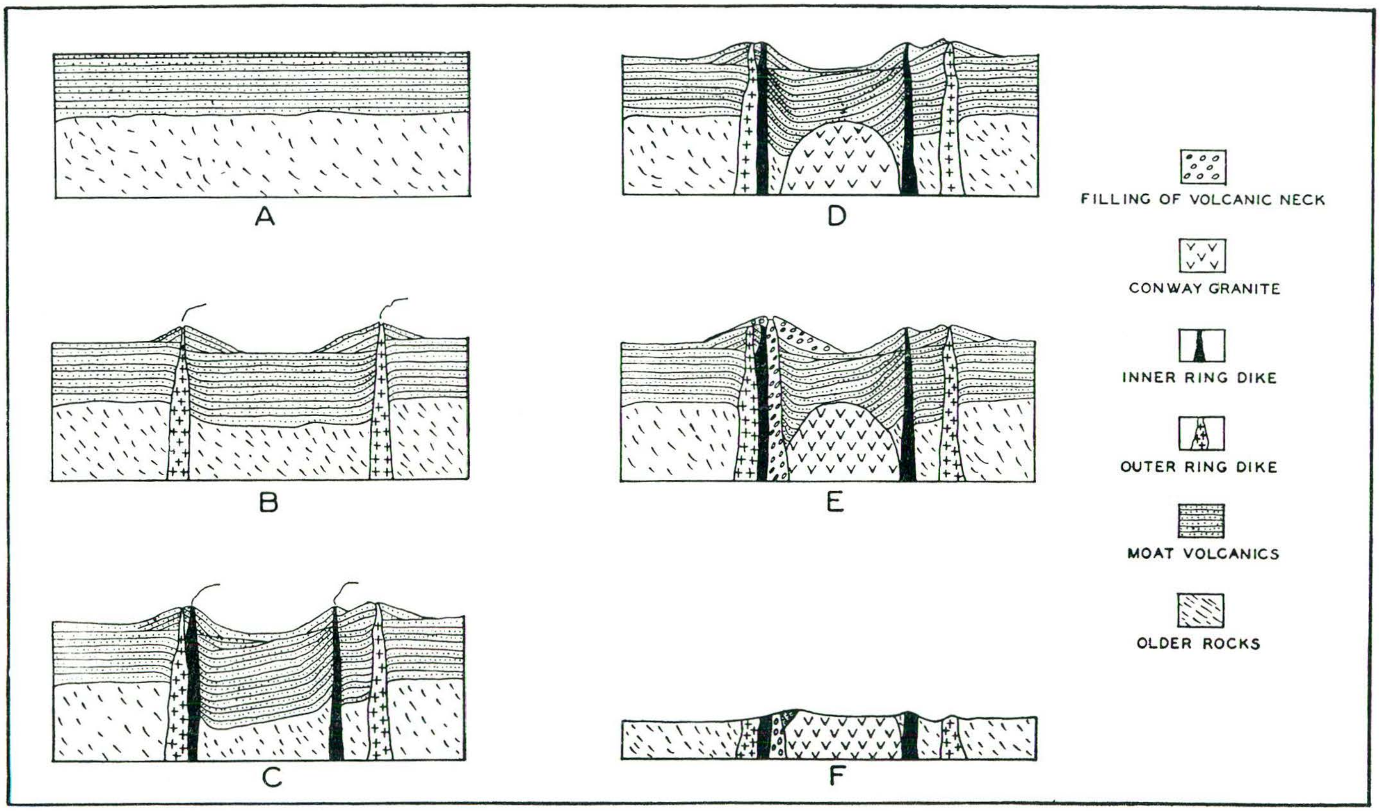

Figure 6

Series of diagrams to illustrate the successive stages in the formation of the Belknap Mountains. See text for complete explanation.

Next, a great fracture, essentially circular in plan but with steep or vertical walls, cut the older rocks. This fracture was some six miles in diameter. Successive injections of molten magma into this fracture formed the outer ring-dike (Figure 5), which is composed of monzodiorite, monzonite, syenite, and quartz syenite. Rattlesnake Island rises sharply above the waters of the lake because the rock of this part of the ring-dike is very resistant to erosion.

A second great fracture, also circular in plan and with vertical walls, developed; its center is some two miles west of the center of the older fracture (Figure 5). The block inside this fracture settled and the Moat volcanics were dropped thousands of feet (Figure 6C). It is for this reason that the volcanics are preserved inside the ring-dike but not outside. At about the same time molten magma rose along the fracture to form the inner ring-dike, composed of quartz syenite.

Still later a great mass of molten magma rose into the western part of the Belknap area, to form the central stock of Conway granite (Figure 6D). Apparently a large central block sank and the magma filled the potential cavity so produced. The last major event in the formation of the rocks of the Belknap Mountains was a large volcanic eruption (Figure 6E). The throat of the old volcano is still preserved in the western part of the Belknap Mountains.

The Moat volcanics, and the rocks in the ring-dikes, the central stock, and the throat of the volcano probably solidified during the Mississippian period, some 270,000,000 years ago. Throughout subsequent geologic time erosion has eaten deep into the Belknap area (Figure 6F) and only the foundations of the former structure remain.

The *Ossipee Mountains* also have an excellent ring-dike, but only part of it lies in the Winnipesaukee quadrangle. The ring-dike is composed of Albany quartz syenite. Excellent exposures of the rocks, especially the Moat volcanics, may be seen along the ridge that contains Bald Knob and the ridge about two miles to the east. From Mt. Shaw there is a striking view of the whole structure. The origin of the Ossipee Mountains is more fully discussed in the pamphlet describing the geology of the Mt. Chocorua quadrangle.

Red Hill, also composed of rocks belonging to the White Mountain Magma series, contains a variety of syenites and granite. It has long been famous among geologists because of the occurrence of the unusual rock, nepheline-sodalite syenite*, and specimens from here may be seen in petrographic laboratories throughout the world. This rock is best exposed at the "Horne Quarry," on the knoll two-tenths of a mile south of the place where the trail leaves the old road to the saddle. The quarry consists of a few shallow pits from which disintegrated rock was dug years ago for roads. The ascent of the main trail to the fire tower gives opportunity to see the nepheline-sodalite syenite and the medium-grained syenite, as well as an excellent view of most of the lake country. The fire tower is on ledges of the medium-grained syenite. Just back of the ranger's cabin is a small trap dike.

Shaping of Today's Scenery

The dikes cutting the other rocks of the White Mountain magma series are the youngest of the hard rocks formed in this area and the millions of years following their formation were taken up with the erosion of all of these rocks into the present topography. Frost and other weathering processes broke the rocks to pieces. One has only to study the "rottenstone" pit in the Belknap Mountains or the "Horne Quarry" on Red Hill to be convinced that the weather can and does break the solid rocks into crumbling masses. The rain washed the loose rock fragments into the streams and running water carried them away. These may seem to the reader like slow processes. They are indeed very slow processes, but geologic time is inconceivably long. The Winnipesaukee quartz diorite was worn away more rapidly than the other rocks and a great lowland was carved out of it. The more resistant rocks stand higher because they were eroded more slowly. Thus, the main features of the present topography were shaped by long years of stream erosion.

*The sodalite in this rock is fluorescent, i. e. it will glow under certain types of ultraviolet light. It generally cannot be recognized except by its fluorescence.

The Great Ice Age

But erosion by streams was at last interrupted. About one million years ago a great ice cap accumulated in Canada. As this ice cap grew bigger, it slowly spread out in all directions. Its southern border crept steadily southward until it completely covered the White Mountains and extended as far south as Cape Cod and Long Island, New York. As it moved, it gripped the soil and plucked out block after block of the bed-rock. The ice thus came to have embedded in it a great load of rock waste of every size, from clay to boulders. Sand, gravel, and boulders in the slowly moving ice polished and scratched the bed rock. Many of these scratches are to be seen today on rock surfaces which have been recently uncovered, although they have generally been obliterated from rock surfaces which have been exposed to the weather during the thousands of years since the glacier disappeared.

The work of the ice sheet, too, was finally halted, for the climate became warmer and the glacier melted away. As this great mass of ice melted, it dropped its load of clay and boulders irregularly about the country. This "glacial drift" is to be seen almost everywhere today. The water that flowed out of the melting ice also carried great quantities of sand and gravel which were spread or heaped irregularly about the area.

The main effects of the great ice age on the present topography are the rounding of the hills by glacial erosion, especially in the lowland, and the deposition of the glacial drift, sand, and gravel. The irregular dumping of glacial drift, sand, and gravel blocked many former stream valleys, and that is the main cause of the lakes in the region.

Only about twenty-five thousand years seem to have elapsed since the ice melted away and the landscape has been changed very little in that time.

HOW TO READ THE MAP

In the envelope at the back of this pamphlet is a geological map. To the right of the map is the legend, that is, the explanation of the colors and patterns used for the various geological formations. At the bottom of the map are three structure sections. The use of the map, legend, and structure sections will be explained in the ensuing paragraphs.

The base map on which these colors and patterns are printed is the regular topographic map, with which many of the readers are doubtless familiar. One inch on the map represents approximately one mile. Roads are shown as double black lines. Trails are single dashed lines; however, certain geological boundaries are shown by a similar broken line. Houses are solid black squares. Lakes and streams are blue; swamps are blue tufts.

At the bottom of the map is a symbol labelled, "approximate mean declination 1906." A line shows true north, an arrow magnetic north, and the angle between them is 13½ degrees. It means that the compass needle here points 13½ degrees west of true north.

The elevations and slope of the land are shown by brown contour lines, and the elevations of certain road corners, water levels of lakes, bridge floors, and other points are indicated by brown or black figures. A contour line is a line drawn through points of equal elevation. The elevation above sea level is marked on some of the lines at 100-foot intervals and the elevation of nearby lines may be determined by counting from the marked lines. On the Winnipesaukee map a contour line is drawn for every twenty-foot difference of elevation, as is indicated at the bottom of the map by the phrase, "Contour interval 20 feet." It will be noticed that every fifth line is a heavy line, and with a 20 foot interval, every heavy line is a hundred-foot line. It is apparent that the map shows the elevation of all points within 20 feet, at most.

The slopes can be determined by the closeness of the contour lines. Where successive lines are far apart the slope is gentle and where they are close the slope is steep. It will be noticed, for instance, that Rattlesnake Island rises steeply from the lake and that, on the contrary, Jolly Island has gentle slopes.

If one studies a contour map carefully he can soon learn to see the hills and valleys at a glance.

The various color patterns indicate different kinds of rock, and letters standing for each kind of rock are printed on each color pattern. So, by referring to the legend it is possible to tell the nature of the bed-rock at any locality. Actually, of course, the bed-rock is exposed only in a small percentage of the area. Sand and glacial till, in places many scores of feet thick, commonly hide it. The geological map, therefore, is a geologist's interpretation of the distribution of the bed-rock, based on knowledge he gathers from the actual exposures. Each geological formation is described in some detail under the legend, but these descriptions are largely for the benefit of the professional geologist and need not concern us here. Geological legends are generally arranged, in so far as possible, with the youngest rocks on top and the oldest at the bottom. Thus, in the Winnipesaukee quadrangle the oldest rock is the Littleton formation, the youngest the trap dikes or the quartz vein. The legend does not show the relationship of the different areas of the White Mountain magma series to each other, however. It does show the relationship of the different rocks within each of these areas. The geological age of the rocks is given by the vertical printing. The Carboniferous age is the time when most of the coal of the eastern United States was deposited; the highest types of animals were those related to the frogs. Devonian time, which has been known as the "age of fishes," was still earlier than Carboniferous.

The symbol used for "strike and dip of foliation and schistosity" (lower right hand column of legend) needs explanation. The foliation and schistosity of these rocks is a banding of the rocks. The geologist finds it necessary to measure the attitude of this foliation. For the purpose of explanation, the foliation may be compared to the roof of a house or the top of a ridge-pole type tent. The "strike," or the line of the symbol, corresponds to the ridge-pole. However, most measurements of strike in the foliated rocks are made in positions which correspond to a place part way down one side of the roof. The strike is still parallel to the ridge-pole. Geologists are also interested in the way the rocks are tilting, or dipping, or whether at a given place it is on the right or the left side of the ridge-pole. The point of the symbol indicates the direction of dip, or downward slant. Foliation may have a steep or a gentle dip, just as some roofs are steeper than others. The number of degrees printed beside the symbol indicates the steepness of the dip; the larger the number, the steeper it is. Zero (though never used) would indicate horizontal foliation; 90 degrees (a right angle) would mean vertical foliation. Special symbols for horizontal foliation and for vertical foliation are given.

The structure sections at the bottom of the map show what we consider the inside of the mountains to be like. If a ditch almost a mile deep were dug along the line A-A′ on the map, the distribution of the rocks seen along the wall of such a ditch would be that shown by section A-A′.

Mineral Resources

The mineral resources of the Winnipesaukee quadrangle seem to be rather poor. There is always the possibility that economically valuable deposits are covered by the sand, gravel, or glacial till, but we have no reason to think that such deposits are actually present.

A very few small granite quarries were opened years ago, but the granite is not very good and has only been used for foundations and walls locally.

The Meredith trap rock quarry at Dudley Leavitt's near Little Pond has been rather active in recent years in producing road metal. There is also a vast amount of trap rock in the Moat volcanics of the Ossipee Mountains, more than anywhere else in the whole state. If it were economically feasible to build highways with trap rock instead of gravel, these mountains could furnish it.

The nepheline-sodalite syenite of Red Hill has distinct possibilities for use in the ceramic industries. Red Hill is perhaps the only place in the whole state where rock of this type is found in sufficient quantity to encourage exploitation. At the present time the rock is not being used because of the difficulty of extracting the harmful iron-bearing minerals. This difficulty may be overcome and it may eventually be used.

The sand and gravel are probably the most valuable resource of the quadrangle, but gravel here is more scarce than almost anywhere else in the state.

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12. Smith, A. P., L. Kingsley, and Alonzo Quinn, "*Geology of the Mount Chocorua Quadrangle,*" State Planning and Development Commission, 1939.

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*Out of print.

MISCELLANEOUS MAPS

Surficial Geology of New Hampshire. Map. 1950. Scale 1 inch equals 4 miles. $1.00

Bedrock Geology of New Hampshire. Map. 1955. Scale 1 inch equals 4 miles. 2.00

Topographic Map of New Hampshire. In three colors at scale of 1 inch equals 4 miles. 100 foot contour lines. Water areas, streams and town lines indicated. Outside dimensions 51'' x 39''. **Out of print.** 1.00

U. S. G. S. Quadrangle Maps. May be purchased at Division Office at 35¢ each. Large quantities of one map should be purchased directly from Director, U. S. Geological Survey, Washington 25, D. C.

AEROMAGNETIC MAPS

The following aeromagnetic maps are on open file at Division Office, Concord, and Geology Department, University of New Hampshire, Durham. They may be purchased for 50¢ each from Distribution Section, U. S. Geological Survey, Washington 25, D. C.

Aeromagnetic Map of the Alton Quadrangle. Map GP 136.
Aeromagnetic Map of the Berwick Quadrangle. Map GP 137.
Aeromagnetic Map of Umbagog Lake and Vicinity. Map GP 138.
Aeromagnetic Map of Berlin and Vicinity. Map GP 139.
Aeromagnetic Map of Littleton and Vicinity. Map GP 194.
Aeromagnetic Map of Woodsville and Vicinity. Map GP 195.
Aeromagnetic Map of Lake Tarleton and Vicinity. Map GP 196.
Aeromagnetic Map of the Mt. Cube Quadrangle and Part of the Rumney Quadrangle. Map GP 297.
Aeromagnetic Map of the Hanover Quadrangle. Map GP 298.
Aeromagnetic Map of the Mascoma Quadrangle and Part of the Cardigan Quadrangle. Map GP 299.
Aeromagnetic Map of the Claremont Quadrangle. Map GP 300.
Aeromagnetic Map of the Sunapee Quadrangle, Map GP 301.
Aeromagnetic Map of the Bellows Falls Quadrangle and Part of the Lovewell Mountain Quadrangle. Map GP 302.
Aeromagnetic Map of the Keene Quadrangle and Parts of the Brattleboro and Monadnock Quadrangles. Map GP 303.

Publications on the Geology of New Hampshire

All Geological publications are allowed a discount of 20% if purchased in quantities of 10 or more of the same publication.

Remittance should be made by postal money, express order or check (payable to the **State of New Hampshire**). Do not send stamps.

Currency may be sent at sendor's risk. Address request to: N. H. Department of Resources and Economic Development, Division of Economic Development, State House Annex, Concord, New Hampshire 03301.

QUADRANGLE REPORTS

Geology of the Alton Quadrangle. Glenn W. Stewart. 1961. 33 p. illus. Maps.	$1.50
Geology of the Bellows Falls Quadrangle. Frederick C. Kruger. 1946. 19 p. illus. Map.	1.00
Geology of the Cardigan and Rumney Quadrangles. Katherine Fowler-Billings and Lincoln R. Page. 1942. 31 p. illus. Maps.	1.00
Geology of the Dixville Quadrangle. Technical Bulletin No. 1. Norman L. Hatch, Jr. 1963. 81 p. illus. Maps.	3.50
Geology of the Franconia Quadrangle. Marland P. Billings and Charles R. Williams. 1935. 35 p. illus. Map. **Out of print.**	.50
Geology of the Gilmanton Quadrangle. Milton T. Heald. 1955. 31 p. illus. Maps.	1.50
Geology of the Hanover Quadrangle. John B. Lyons. 1958. 43 p. illus. Map.	1.00
Geology of the Isles of Shoals. Katherine Fowler-Billings. 1959. 51 p. illus. Map. **Out of print.**	1.00
Geology of the Keene-Brattleboro Quadrangle. George E. Moore, Jr. 1949. 31 p. illus. Map.	1.00
Geology of the Littleton and Moosilauke Quadrangles. Marland P. Billings. 1935. 51 p. illus. Maps. **Out of print.**	.60
Geology of Lovewell Mountain Quadrangle. Milton T. Heald. 1950. 29 p. illus. Map.	1.00
Geology of the Monadnock Quadrangle. Katherine Fowler-Billings. 1949. 43 p. illus. Map.	1.00
Geology of Mt. Chocorua Quadrangle. Althea Page Smith, Louise Kingsley, Alonzo Quinn. 1939. 24 p. illus. Map.	
Geology of the Mt. Cube and Mascoma Quadrangles. Jarvis B. Hadley and Carleton A. Chapman. 1939. 28 p. illus. Maps. **Out of print.**	.60
Geology of Mt. Pawtuckaway Quadrangle. Jacob Freedman. 1950. 34 p. illus. Map.	1.00
Geology of the Mt. Washington Quadrangle. Marland P. Billings, Katherine Fowler-Billings, Carleton A. Chapman, Randolph W. Chapman, Richard P. Goldthwait. 1946. 56 p. illus. Maps.	
Geology of the Percy Quadrangle. Randolph W. Chapman. 1949. 38 p. illus. Map.	1.00
Geology of the Plymouth Quadrangle. Charles B. Moke. 1946. 21 p. illus. Map.	1.00

Geology of the Sunapee Quadrangle. Carleton A. Chapman. 1953. 32 p. illus. Map. $1.00

Geology of the Winnipesaukee Quadrangle. Alonzo Quinn. 1941. 22 p. illus. Map.

Geology of the Wolfeboro Quadrangle. Alonzo Quinn. 1953. 24 p. illus. Map. 1.00

GEOLOGICAL QUADRANGLE MAPS

Maps of the following quadrangles may be purchased at 50 cents each. A 20% discount allowed in quantities of 10 or more of the same map: Dixville, Hanover, Keene-Brattleboro, Lovewell Mountain, Mascoma, Monadnock, Mt. Chocorua, Mt. Cube, Mt. Pawtuckaway, Percy, Plymouth, Sunapee, Wolfeboro. The following quadrangle maps are **out of print:** Cardigan, Franconia, Littleton, Moosilauke, Rumney, Winnipesaukee, Woodsville, Bellows Falls.

MINERAL RESOURCE REPORTS

New Hampshire Minerals and Mines. T. R. Meyers. 1941. 49 p. Map. **Out of print.** See Geology of New Hampshire, Part III. $ .50

NEW HAMPSHIRE MINERAL RESOURCES SURVEY:

Part	I.	**General Summary.** H. M. Bannerman. 1940. 9 p. Reprinted 1960.	$ .40
Part	II.	**Diatomaceous Earth.** Andrew H. McNair. 1941. 6 p. Map.	.10
Part	III.	**Peat Deposits in New Hampshire.** George W. White. Analyses by Gordon P. Percival. 1941. Reprinted 1949. 16 p. Map.	.25
Part	IV.	**Sillimanite, Andalusite, Kyanite, and Mica Schist Deposits.** H. M. Bannerman. 1941. Reprinted 1949. 5 p.	.25
Part	V.	**Fluorite Deposits of Cheshire County.** H. M. Bannerman. 1941. Reprinted 1949. 9 p. illus. Maps.	.25
Part	VI.	**Quartz.** T. R. Meyers. 22 p. Maps. 1941. Reprinted 1963.	.25
Part	VII.	**Structural and Economic Features of Some New Hampshire Pegmatites.** H. M. Bannerman. 22 p. Maps. 1943. Reprinted 1950.	.30
Part	VIII.	**Sillimanite Deposits in Monadnock Quadrangle.** Katherine Fowler-Billings. 1944. Reprinted 1949. 14 p. illus. Maps.	.25
Part	IX.	**Mineral Composition of New Hampshire Sands.** J. W. Goldthwait. 1948. 7 p. Map.	.10
Part	X.	**Glacial Till in New Hampshire.** Lawrence Goldthwait. 1948. 11 p. Map.	.10
Part	XI.	**Artesian Wells in New Hampshire.** Richard P. Goldthwait. Studies by J. W. Goldthwait, D. H. Chapman, L. Goldthwait. 1949. 24 p. illus. Reprinted 1958.	.30
Part	XII.	**Clays of New Hampshire.** Preliminary Report. Donald H. Chapman. Physical test of clays by Willard J. Sutton; chemical tests of clays by M. J. Rice. 1950. 27 p. Map.	.25
Part	XIII.	**Foundry Sands of New Hampshire.** Preliminary Report. T. R. Meyers. Mechanical analyses by Willis C. Campbell. 1950. 32 p. Map.	.30
Part	XIV.	**Feldspar and Associated Pegmatite Minerals in New Hampshire.** J. C. Olson. 1950. 50 p. Maps.	.65

Part XV.	**Clays of Southeastern New Hampshire.** Preliminary Report. Lawrence Goldthwait. 1953. 15 p. Map.	$ .50
Part XVI.	**Sands of the Merrimack Valley.** Preliminary Report. Lawrence Goldthwait. 1957. 19 p.	.50
Part XVII.	**Lightweight Aggregate Raw Materials in New Hampshire.** Preliminary Report. Glenn W. Stewart. 1959. 30 p.	1.00
Part XVIII.	**Suburban and Rural Water Supplies in Southeastern New Hampshire.** T. R. Meyers and Edward Bradley. 1960. 31 p.	.75

THE GEOLOGY OF NEW HAMPSHIRE (In three volumes.):

Part I.	**Surficial Geology.** James W. Goldthwait, Lawrence Goldthwait, Richard P. Goldthwait. 1951. 83 p. Includes Surficial Geology map at scale of 1 inch equals 4 miles. Reprinted 1963.	$1.50
Part II.	**Bedrock Geology.** Marland P. Billings. 1956. 203 p. Includes Bedrock Geology Map at scale of 1 inch equals 4 miles. Reprinted 1962.	3.50
Part III.	**Minerals and Mines.** T. R. Meyers and Glenn W. Stewart. 1956. 107 p. Map. Reprinted 1964.	1.50

MISCELLANEOUS REPORTS AND REFERENCES

Ore Hill Zinc Mine, Warren, New Hampshire. H. M. Bannerman. 1943. 2 p. Map. Reprinted 1962.	$ .10
Mineral Resources in the Lakes Region. Report of the Mineral Resources Committee, Lakes Region Survey. May, 1945. 10 p. Map. **Out of print.**	
Geologic Story of Franconia Notch and the Flume. Andrew H. McNair. 1949. 14 p. illus.	.20
Geology Story of Kinsman Notch and Lost River. Andrew H. McNair. 1949. 14 p. illus.	.20
The Mountains of New Hampshire. A directory locating the mountains and prominent elevations of the State. 1949. 145 p. illus.	.50
New Hampshire Water. Governmental responsibilities and activities in relation to the water resources of New Hampshire. December 1953. Maps. Charts.	2.00
Mica-bearing Pegmatites of New Hampshire. U. S. Geological Survey Bulletin. 931 p. Preliminary Report. J. C. Olson. 1941. 41 p. Maps.	Free

The following reports should be purchased directly from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402:

Pegmatite Investigations, 1942-45, New England. U. S. Geological Survey Professional Paper 255. Eugene N. Cameron and others. 1954.	
Beryl Resources of New Hampshire. U. S. Geological Survey Professional Paper 353. James J. Page and David M. Larrabee. 1962.	$4.00
New Hampshire Basic-Data Report No. 1, Ground-Water Series, Southeastern Area. Edward Bradley and Richard G. Petersen. Prepared by the U. S. Geological Survey in cooperation with the New Hampshire Water Resources Board. 1962. 53 p. Maps. (Available from N. H. Water Resources Board, Concord, N. H.)	